

Simulation of the SNS CCL BPM High Frequency Performance

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This simulation examines the high frequency signal power of the CCL BPMs as a function of beam energy and beam micropulse shape, for the present design BPM.

===== basic constants =====

$$c := 2.997924 \cdot 10^{10} \text{ cm/sec} \qquad Mc2 := 939.28 \text{ MeV}$$

===== beam properties =====

$$I_b := 0.038 \qquad f := 402.5 \cdot 10^6 \qquad w := 2 \cdot \pi \cdot f$$

$$\text{gam}(E) := 1 + \frac{E}{Mc2} \qquad \text{bgam}(E) := \sqrt{\text{gam}(E)^2 - 1} \qquad \text{beta}(E) := \frac{\text{bgam}(E)}{\text{gam}(E)}$$

===== BPM =====

$$a := 1.71 \text{ cm, effective radius} \qquad L := 4.20 \text{ cm, effective length}$$

$$Z := 50 \text{ ohms} \qquad \text{phi} := 60 \text{ degrees, electrode width}$$

$$\text{argBPM}(n, E) := \frac{n \cdot w \cdot L}{2 \cdot c} \cdot \left(1 + \frac{1}{1} \right) \quad \text{argument for BPM with shorted electrodes}$$

===== Bessel factor =====

This is the low-beta effect

$$\text{argBes}(n, E) := \frac{n \cdot w \cdot a}{\text{bgam}(E) \cdot c} \qquad \text{Bes}(n, E) := \frac{1}{I_0(\text{argBes}(n, E))} \qquad \text{dB change} \\ \text{dBBes}(n, E) := 20 \cdot \log(\text{Bes}(n, E))$$

===== Fourier transform of pulse shape =====

$$\text{FWAB}(\text{sig}) := 4.472 \cdot 10^{-12} \cdot \text{sig} \quad \text{Full width at base of parabolic micropulse, in terms of the rms width sig(ps).}$$

$$\text{alpha}(n, \text{sig}) := n \cdot \pi \cdot \text{FWAB}(\text{sig}) \cdot f$$

$$\text{Am}(n, \text{sig}) := 3 \cdot \left(\frac{\sin(\text{alpha}(n, \text{sig}))}{\text{alpha}(n, \text{sig})^3} - \frac{\cos(\text{alpha}(n, \text{sig}))}{\text{alpha}(n, \text{sig})^2} \right) \quad \text{Fourier harmonic amplitudes for parabolic bunch shape}$$

$$\text{dBpulse}(n, \text{sig}) := 10 \cdot \log(\text{Am}(n, \text{sig})^2) \quad \text{dB change}$$

===== coax cable=====

atten := -2 approx attenuation for 50 m of 1/2" heliax at 400 MHz
 dBatten(n) := atten· $\sqrt[3]{n}$ dB change

===== dBm power for basic BPM =====

$$V(n, E) := \sqrt[3]{2} \cdot \frac{\text{phi}}{360} \cdot I_b \cdot Z \cdot \sin(\arg\text{BPM}(n, E))$$

$$\text{pwr}(n, E) := 1000 \cdot \frac{V(n, E)^2}{Z} \quad \text{milliwatts}$$

dBm(n, E) := 10·log(pwr(n, E)) dBm output for basic BPM without corrections

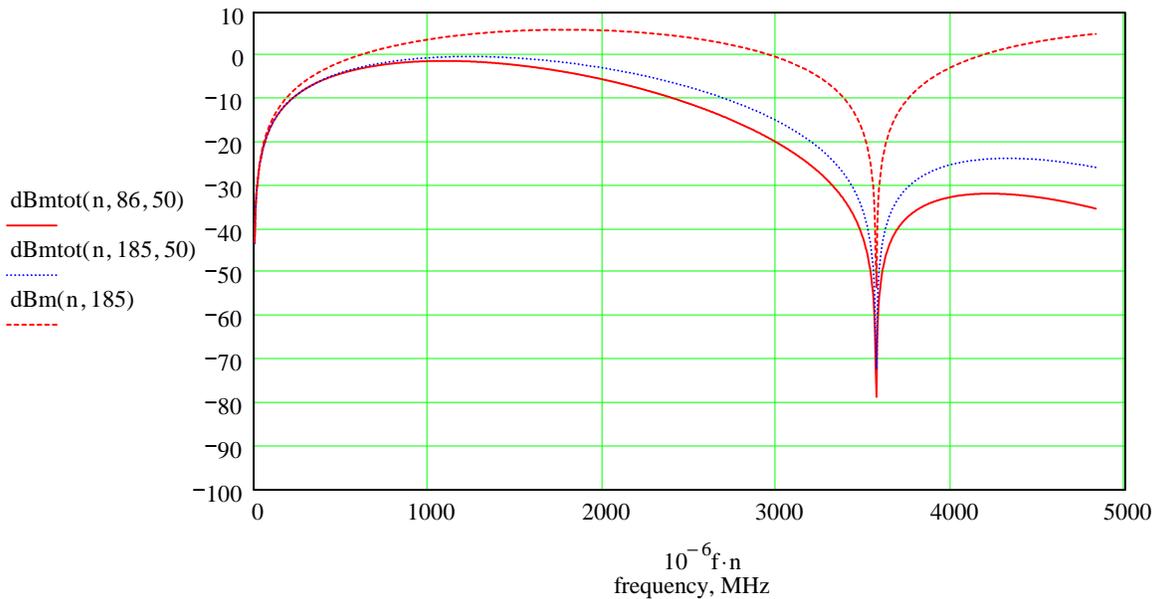
===== total power level =====

$$\text{dBmtot}(n, E, \text{sig}) := \text{dBm}(n, E) + \text{dBBS}(n, E) + \text{dBatten}(n) + \text{dBpulse}(n, \text{sig})$$

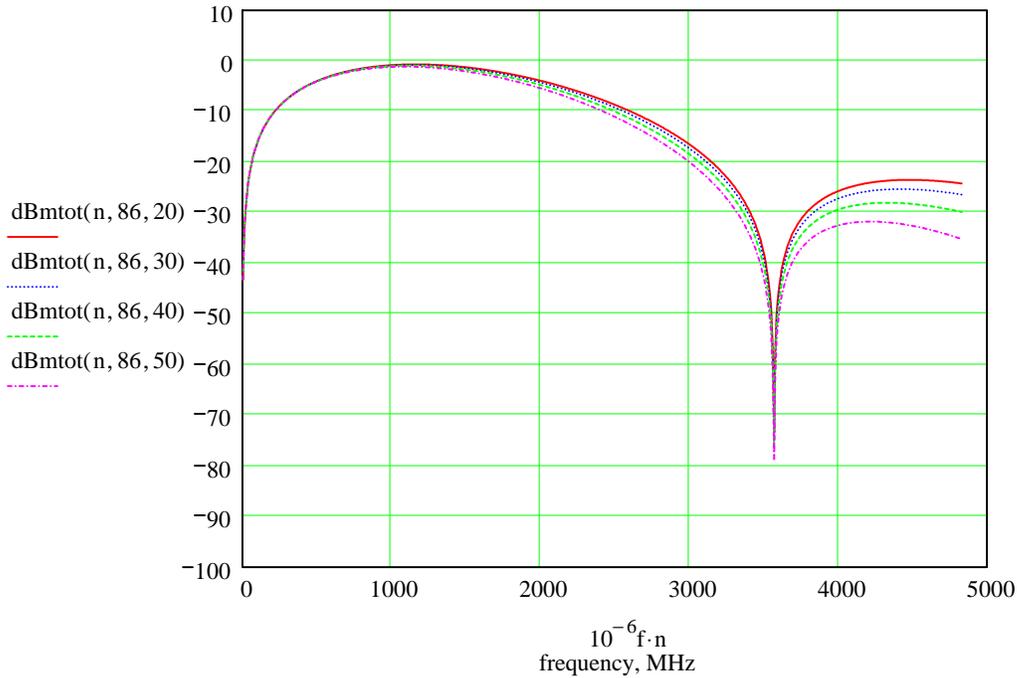
Example dBm(8, 86) = -4.357 dBBS(8, 86) = -11.263
 dBpulse(8, 50) = -4.829 dBmtot(8, 86, 50) = -26.106 dBatten(8) = -5.657

n := 0.01, 0.02.. 12

Signal power vs. frequency for the basic BPM, and for 86 and 185 MeV



Effect of bunch length on output power at 86 MeV



Because the effective length of the BPM is known to only about +/-3%, the signal power between above about 3.4 GHz is very uncertain. It is clear that the best high frequency measurements would be between 2.8 and 3.3 GHz. It may be possible to make measurements near 4 GHz, where the output power is more sensitive to the bunch length.

The approximate cutoff frequencies are (using the effective radius of BPM):

$$f_{TE} := \frac{10^{-9} \cdot 3.832 \cdot c}{2 \cdot \pi \cdot a} \quad f_{TE} = 10.692 \quad \text{GHz, TE mode}$$

$$f_{TM} := \frac{10^{-9} \cdot 2.405 \cdot c}{2 \cdot \pi \cdot a} \quad f_{TM} = 6.711 \quad \text{GHz, TM mode}$$

Measurements probably should be limited to about 3.2 GHz or lower.

$$8 \cdot 10^{-9} \cdot f = 3.22 \quad \text{GHz}$$

Amplitudes of the 8th harmonic (about 3.2 GHz) are:

$$\text{dBmtot}(8, 86, 10) = -21.455 \quad \text{dBm, 10 ps rms bunch length}$$

$$\text{dBmtot}(8, 86, 20) = -21.996 \quad \text{dBm, 20 ps rms bunch length}$$

$$\text{dBmtot}(8, 86, 30) = -22.921 \quad \text{dBm, 30 ps rms bunch length}$$

$$\text{dBmtot}(8, 86, 40) = -24.268 \quad \text{dBm, 40 ps rms bunch length}$$

$$\text{dBmtot}(8, 86, 50) = -26.106 \quad \text{dBm, 50 ps rms bunch length}$$